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# Sensitivity and specificity of CT scan in revealing skull fracture in medico-legal head injury victims

Hitesh Chawla[1], Rohtas K Yadav[2], Mahavir S Griwan[3], Ranjana Malhotra[4], Pramod K Paliwal[1]

1. Dept. of Forensic Medicine, SHKM Government Medical College, Nalhar, Mewat-Haryana, India
2. Dept. of Radiodiagnosis, Pt. B. D. Sharma PGIMS Rohtak, Haryana, India
3. Dept. of Surgery, Pt. B. D. Sharma PGIMS Rohtak, Haryana, India
4. Dept. of Microbiology, Pt. B. D. Sharma PGIMS Rohtak, Haryana, India

## RESEARCH

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**Corresponding Author:**
Dr Hitesh Chawla
Assistant Professor
Department of Forensic Medicine
SHKM Govt. Medical College Nalhar, Mewat
Haryana, India
Email: drhiteshchawla@gmail.com

## ABSTRACT

### Background
Emergency departments rely on CT scans to manage trauma victims, especially for head injuries. Although the detection of an undisplaced fracture on a CT scan of the head without significant intracranial findings may be insignificant for a clinician, such cases are of paramount importance for medico-legal purposes because they help ascertain the nature, manner, and cause of the head injury.

### Aims
The study was conducted with the objective of knowing the sensitivity and specificity of ante-mortem CT scan findings indicating the presence or absence of skull fractures.

### Methods
Findings were confirmed during post-mortem examination of the subjects who had died during management but who had not had any surgical intervention. A comparative study of ante-mortem CT scan and autopsy findings with respect to fracture in traumatic head injuries was undertaken on 60 deceased individuals brought in for medico-legal post-mortem examination over a period of two years.

### Results
Considering the autopsy findings as the gold standard, we have concluded that 14.6 per cent of the fractures were missed on CT scan findings compared to fractures found during autopsy. The sensitivity of CT scan for skull fractures was found to be 85.4 per cent and specificity was 100 per cent. Kappa was 0.787, which shows good agreement with $p<0.001$, which was highly significant.

### Conclusion
In developing countries, images are interpreted in the axial plane only on a CT scan of the head, which may be due to a lack of financial and human resources. For better delineation of fractures, the use of techniques like multi-detector CT with sagittal and coronal reformations should be considered in the routine interpretation of a CT scan of the head.

### Key Words
CT scan, skull fracture, sensitivity, autopsy

### What this study adds:

**1. What is known about this subject?**
CT is considered the gold standard for managing trauma victims, especially for head injuries. Emergency departments rely on CT scans for rapid and accurate assessment of injuries.

**2. What new information is offered in this study?**
In developing countries, images are interpreted in the axial plane only on a CT scan of the head. A significant number of skull fractures are missed on CT images in the axial plane.

**3. What are the implications for research, policy, or practice?**

For better delineation of fractures, multi-detector CT with sagittal and coronal reformations should be considered in the routine interpretation of a CT scan of the head, so that forensically important fractures are not missed.

## Background

Head injury is the leading cause of morbidity and mortality in India, as well as in other developing countries. Each year in India, nearly two million people are injured with about one million deaths due to head injury. Sixty per cent of the total cases are due to road traffic accidents, followed by falls, and violence.[1] Computerised tomography (CT) scan is the primary screening modality of investigations in head trauma victims.[2,3] The merits of CT for assessment of head injury are its sensitivity for demonstrating bone injuries apart from mass effect, ventricular size, configuration, and acute haemorrhage.[4]

Since the inception of the CT scan in 1971 by Sir Godfrey Hounsfield, CT imaging has advanced significantly from time-intensive single-section scanning to multi-detector row CT, which enables acquisition of isotropic datasets with a voxel dimension of ≤0.6mm.[5] Emergency departments rely on CT scans for rapid and accurate assessment of injuries.[6] In clinical settings the diagnosis of an isolated, undisplaced fracture is not important provided there are no clinical symptoms or complications; however, such a diagnosis has importance in medico-legal cases to ascertain the nature, manner, and mechanism of injury.

The presence or absence of fracture defines the nature of injury whether it is simple or grievous (as per Section 320 of the Indian Penal Code), which is very important from a medico-legal point of view. The radiological investigations are relied upon for inferring the nature of injury in all medico-legal injury victims in general and traumatic head injury in particular. Many times forensic evaluation of clinical cranial CT is the only reliable source of morphological evidence in head injuries. When death is delayed in trauma cases, autopsy findings are then characterised by secondary changes. Moreover, when the injured survives, the evaluation of CT images is the only valuable source of evidence of head trauma available to forensic experts.[7]

Situations do occur when no significant abnormality is evident on a CT scan, whereas the autopsy report suggests otherwise. In such circumstances, a forensic pathologist may find himself in an awkward situation. He is unable to give an accurate opinion regarding the presence or absence of fractures based on reporting of radiological investigations. Often conflict also arises in the court of law when a CT scan report shows no fracture, while the autopsy report reveals a skull fracture. Studies are needed to know the precision and accuracy of a CT scan, which can be achieved only by comparing a CT scan with post-mortem revaluations.

## Method

The study was conducted in a tertiary care institute in northern India. For this study, 60 cases of traumatic head injuries were compiled over a two-year period. In the selected cases patients underwent a CT scan of the head prior to death and none underwent surgical intervention. All 60 cases had medico-legal autopsy. A detailed examination and dissection of the head as per standard forensic autopsy procedure was carried out. After reflecting the scalp, dissecting the temporal muscles, and denuding the periosteum, the fractures on the outer table were noted down. The cranium was opened with an oscillating saw; fractures were noted on the inner table and over the base of skull after removal of brain with dura mater. The fractures found at autopsy were noted down and compared with CT images, which were collected from the hospital records of the deceased. The CT scans were carried out on a spiral CT scanner (SIEMENS make SOMATOM with volume zoom +4). In the CT scan, 5mm contiguous slices were acquired at an angle of 15–20 degrees to the cantho-meatal line from the base of skull to the vertex in the axial plane. The CT films were retrospectively reviewed again by the senior radiologist for confirmation of findings reported by the resident radiologist.

The data collected was tabulated and comparatively evaluated. SPSS statistical software version 16.0 was applied to analyse the scientific data. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were determined by using 2x2 contingency tables for CT and autopsy, taking autopsy findings as the gold standard.

## Results

Most victims were male aged 21–30 years (28.33 per cent), followed by 31–40 years (21.67 per cent). The ages ranged from five years to 80 years with mean 37.53 and standard deviation of 17.616. During post-mortem examination, skull fractures were detected in 41 victims (68.3 per cent), 19 deceased (31.7 per cent) had no fracture. For the CT scans, skull fractures were reported for 35 victims (58.3 per cent),

while in 25 victims (41.7 per cent) there was no radiological evidence of fracture.

Skull fractures were noted in 41 (68.3 per cent) and 35 (58.3 per cent) of autopsies and CT scans, respectively. Of the skull fractures, 14.6 per cent were missed on the CT scans compared to autopsies. No missed fractures were detectable even on retrospective review of CT films by a senior radiologist. Five linear fractures and one depressed fracture were missed on the CT scans, which were evident in the autopsies. Out of five linear fractures that were missed, two were at the fronto-parietal area, one at occipital, one in temporal, and one was over the base of the skull. Depressed fractures missed on CT scans were situated over the frontal area. The sensitivity of the CT scan for fractures was 85.4 per cent, and specificity was 100 per cent with accuracy of 90 per cent. Kappa was 0.787, which shows good agreement with $p$ <0.001, which was highly significant.

## Discussion

For a fracture to be detected on a CT scan there must be discontinuity of the skull. A linear fracture that comes in the plane of a CT slice may not be visualised. A CT scan may have an advantage for radiography for base of skull fractures, provided the plane of slice involves the fracture line.[3,8,9] Linear fracture of the calvarium and cranial base are difficult to be identified by CT scan unless depressed or separated.[10] Depressed fractures may sometimes require coronal reconstructions for delineation.[3] A high spatial resolution CT scan with a thickness of 3mm or less is required to delineate a fracture in a suspected basilar skull fracture.[3]

Thin sections of axial and direct coronal imaging with bone algorithm reconstruction are recommended for delineation of temporal bone fractures. Imaging in the coronal plane can be difficult in trauma patients especially if intubated or having suspected cervical spine injury. In such cases, thinner section axial imaging can be performed with multi-detector CT (MDCT) and coronal reformats can be made out for interpretation.[9] MDCT with multi-planar reconstructions may be required for diagnosis of temporal bone fractures. It is also efficacious in the diagnosis and management of poly-trauma patients in emergency departments.[11]

Moreover, head injury patients are non-cooperative and irritable, and sedation is not recommended as per treatment protocol of such cases. If there is sudden movement of the patient at the time of imaging in that particular plane where the fracture lies, there is a greater chance of a fracture being missed.

In comparison to our results, in one of the earlier studies the overall sensitivity of CT for skull fractures was 25.7 per cent where images were acquired on helical CT scanner at thickness of 5mm for the base of the skull and 10mm for the vertex.[6] Pathak et al. stated that "though CT scan is a common and reliable tool for diagnosis in severe head injury, many a times there is no detectable lesion seen in the CT scan of a patient with severe head injury to explain the neurological status."[12] The CT scan detected only 27 per cent of the fractures in their study.[12]

Sharma and Murari observed that compared to a CT scan, autopsy was found to be more effective in detecting various lesions of head injury.[13] CT is merely an interpretation of images, while autopsy is direct visualisation of the lesions, so it can delineate more pathological findings. In their observations, 23.7 per cent of skull fractures remained undiagnosed by CT scan.[13] Goel et al. observed that CT scans detected fewer fractures (55.2 per cent) compared to conventional autopsy findings.[14] Anand et al. also stated that discrepancies exist between CT and autopsy findings with regard to skull fractures.[15] CT scans revealed fractures of the vault in 29 cases and fractures of the base of the skull in 11 cases, while autopsy results revealed that fractures were observed in the vault in 39 cases and the base of the skull in 31 cases.[15]

Jacobsen et al. observed that fracture details important from a forensic point of view were better delineated in CT images on reconstruction into multi-planar and maximum intensity projection.[16] Wei et al. stated that as coronal reformations can be easily raised from typical non-contrast cranial CT (NCCT) data acquisitions, it should be done as routine for CT examination especially in head injury patients. Many of the findings in head injury victims may be missed if CT images are interpreted in the axial plane only. Skull fractures, when they lie parallel to the acquisition plane, may be completely missed on axial images. The lesions that lie in the axial plane immediately adjacent to bony surface are better delineated during coronal reformations.[5]

CT scans have a low level of accuracy in detecting traumatic injuries, whereas definitive diagnosis is required in forensic pathology.[6] Therefore, a CT scan is an inadequate detection tool for forensic experts. A CT scan is an excellent accomplice for clinicians in emergency room settings but inadequate for courtroom testimony. There is high probability of imprecise indictments and convictions if a CT scan is the sole basis of an evidence.[6] However, a CT scan can be a useful tool in cases where an autopsy report is

imprecise or unreliable.[17] The main limitation in our study was that scanning and viewing was performed only in the axial plane. Many of the fractures missed may have been detected if the scanning protocol using multi-detector CT technique with coronal and sagittal reformats have been used. Further studies can be accomplished by comparing multi-planar reformations of CT skull images with that of autopsy findings.

## Conclusion

This study shows that skull fractures are missed in significant numbers on CT images in the axial plane, with 14.6 per cent of fractures being missed on CT scans when compared to autopsy. In developing countries, images are interpreted in the axial plane only on a CT scan of the head, which may be due to lack of financial and human resources. For better delineation of fractures, the use of multi-detector CT with sagittal and coronal reformations should be recommended in the routine interpretation of a CT scan head, so that forensically important fractures are not missed.

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